ACTA UNIVERSITATIS AGRICULTURAE ET SILVICULTURAE MENDELIANAE BRUNENSIS

Volume 62 117 Number 5, 2014

http://dx.doi.org/10.11118/actaun201462051109

MONITORING OF VEGETATIVE PHENOLOGICAL STAGES IN EUROPEAN BEECH (*FAGUS SYLVATICA* L.) GROWING IN A MIXED STAND

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Abstract

SLOVÍKOVÁ KRISTÝNA, BEDNÁŘOVÁ EMILIE. 2014. Monitoring of Vegetative Phenological Stages in European Beech (*Fagus sylvatica* L.) Growing in a Mixed Stand. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis,* 62(5): 1109–1115.

The paper presents results of monitoring of beech (*Fagus sylvatica* L.) vegetative phenophases within the period of years 2005–2010 as related to results of evaluation involving data collected since 1991. This phenological study was performed in a young mixed forest stand situated in the Drahanská vrchovina uplands in the altitude of 625 m.a.s.l. Beginnings and duration of individual phenophases differed in dependence on the course of weather conditions in individual years of study. The highest variability was observed in the stage of budbreak. The obtained results indicate that the onset of spring phenophases was dependent on temperatures existing already in early spring and to the end of winter period. The statistical analysis proved a high correlation existing between the onset of spring phenophases on the one hand and soil and air temperatures on the other. Temperature requirements as defined for the beginnings of individual phenophases were evaluated on the base of cumulative sums of temperatures higher than 0 °C. The obtained results indicate that, as compared with results of long-term monitoring, the period of the duration of spring phenophases had been gradually shortened. On the other side, however, the duration of autumn phenophases was extended and they ended in the late autumn. Repeated extensions of the growing season to the detriment of winter dormancy might show a negative effect on the health condition of forest stands.

Keywords: European beech, phenological stages, air temperature, soil temperature, growing season, mixed stand, weather

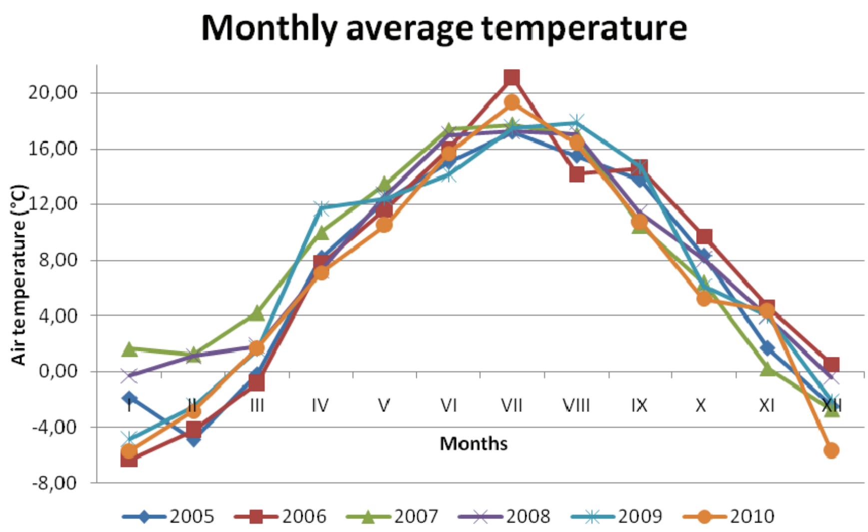
INTRODUCTION

The phenological monitoring enables to study patterns and the course of life processes taking place in plants and their dependence on environmental conditions. They enable to get valuable data about the onset and duration of the growing season in different climatic regions. Although the character of individual phenophases of forest woody species is markedly periodic, it can be said that they are significantly influenced also by environmental conditions, above all by the weather. Due to current climatic changes, the onset of individual phenophases can be shifted so that the norma development of plants can be disturbed (Larcher, 1988). The dependence of tree phenology on climatic signals is well established (Sparks *et al.*, 2006; Bednářová *et al.*, 2010; Bednářová & Merklová, 2007; Merklová & Bednářová, 2008, Škvareninová, 2013).

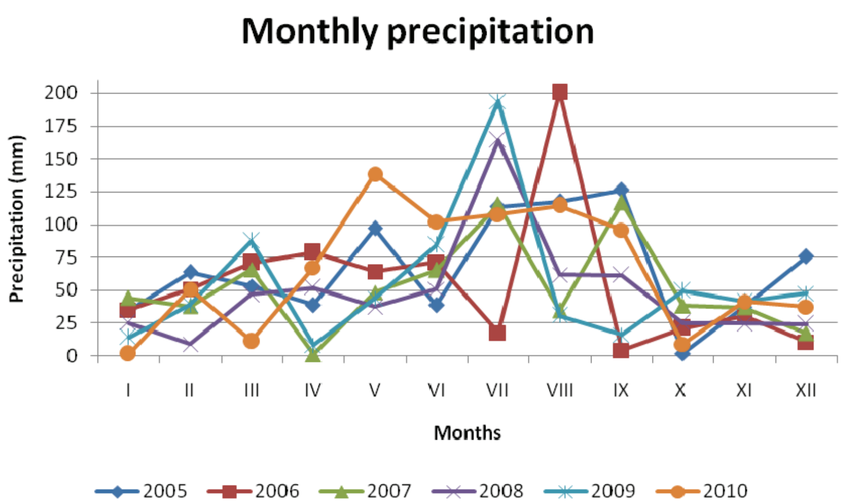
The monitoring of phenophases and their evaluation may be used as a bioindicator of climatic changes. As far as individual woody species are concerned, an earlier onset and the changing duration of these phenophases is an indicator of the existence of such processes. The importance of phenological observations consists above all in a possibility to explain mutual relationships and correlations existing between phenological trends and climatic changes (Škvareninová, 2010; Gömöry, 2010). Long-term phenological records may provide information at the level of individual species so that they enable to explain biological responses of plants to climatic changes in individual regions under study (Švareninová, 2013). Recently published papers (Bartošová *et al.*, 2010; Amano *et al.*, 2010; Beaubien & Hamann, 2010) indicate that due to a gradual warming of the atmosphere individual phenophases begin earlier and earlier. Global studies concerning changes in plant phenology indicate that in medium and higher altitudes of the northern hemisphere the onset of individual phenophases occurs earlier in the spring and that the growing season extends to the late autumn so that the period of dormancy is shorter and shorter (Hájková *et al.*, 2010; Možný & Nekovář, 2007; Škvareninová, 2009).

MATERIAL AND METHODS

Phenological observation of European beech (*Fagus sylvatica* L.) have been carried out on the research plot of the Institute of Forest Ecology, Mendel University in Brno, Czech Republic, within the period of 2005–2010. In this locality, phenological studies have been carried out already since 1991. The research plot is situated on the north-eastern to eastern slopes of the watershed ridge in the altitude of 625 m.a.s.l. The area is characterized by coordinates 16° 41´30´´E and 49° 26´31´´ N in the geographical unit of the Drahanská vrchovina uplands. Precipitation and temperature characteristics of the locality in years 2005–2010 are presented in Figs. 1 and 2. The species composition of trees of a 32-year-old mixed forest stand is as folows: *Picea abies* /L./ Karst 60%, *Fagus sylvatica* L. 30%, *Larix decidua* Mill. 10%. Phenological observations were carried out according to the methodology of the Czech



1: *Monthly average of air temperature in the years 2005–2010*



2: *Monthly totals precipitation in the years 2005–2010*

Hydrometeorological Institute (Hájková *et al*., 2012) and observed were the following phenological stages: breaking of buds (budbreak), leafing 10%, leafing 50%, leafing 100%, fully leaved, 10% of leaves discoloured, 100% of leaves discoloured, 10% of leaves fallen, 100% of leaves fallen. The day ordinal numbers from the beginning of a calendar years were assigned to the date of particular phenological stages. Sums of average daily temperatures higher than 0 °C (TS0) were calculated for each phenophase. Sums of soil temperatures measured in corresponding phenophases were assessed at the level above 0 °C. In the forest stand under study, air temperatures were monitored by means of the Datalogger Minikin T sensor placed on the lower margin of crowns. The soil temperature was measured with the MicroLog SP sensor at the depth of 20 cm. For monitoring of precipitations, the Climatronics rain gauge and the datalogger MicroLog ER were installed in the open area.

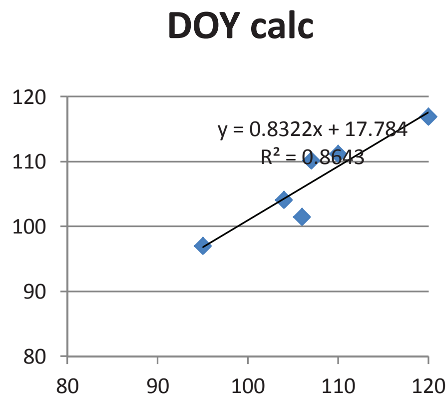
RESULTS AND DISCUSSION

The Onset and Duration of Individual Phenophases as a Response to Weather Variability

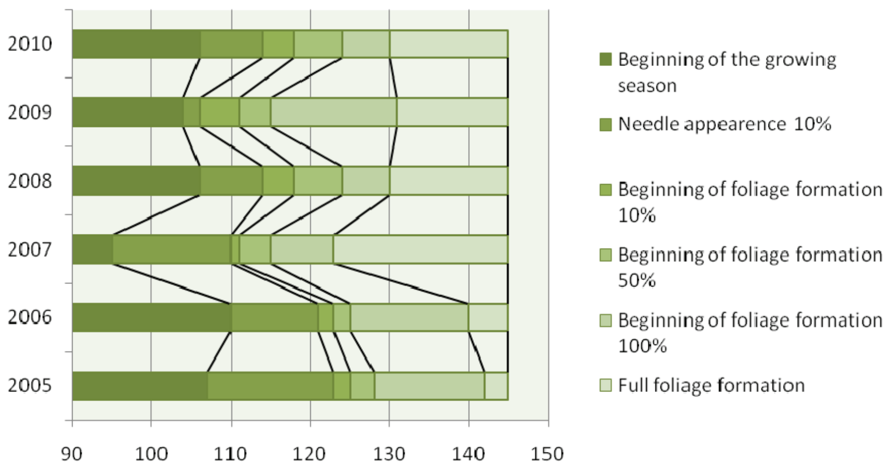
In individual years, the onset and duration of spring phenophases was very variable and depended on the course of weather conditions. The time course of spring phenophases in European beech (*Fagus sylvatica* L.), as recorded in individual years, is presented in Fig. 3. Within the period of 2005–2010, the beginning of budbreak phenophase occurred in average on the 107th day of the calendar year (with the variability of 25 days) depending on the end of winter and the onset of temperatures enabling the advent of spring phenophases. The phenophase of 10% of leaves began in average on the 116th day of the calendar year (with the variability of 17 days). The phenophase of 50% of leaves started in average on the 119th day of the calendar year (with the variability of 15 days) and the phenophase of 100% of leaves occurred in average on the 122nd day of the calendar year (with the variability of 13 days). In European beech (*Fagus sylvatica* L.), the full development of leaf area took place on the 134th day of the calendar year (with the variability of 19 days). It was found out that within the whole study period (i.e. 1991–2010), the most variable of all spring phenophases was that of the budbreak.

The statistical analysis demonstrated that the onset of this phenophase was dependent on air and soil temperatures existing in the preceding month. This analysis also demonstrated that the dependence of phenophases only on air temperature was lower while that on soil temperature was higher. As shown in Fig. 4, multiple regression functions showed that the dependence of budbreak on both soil and air temperatures was very high (R^2 = 0. 8643 ($y = 0.8322x + 17.784$)).

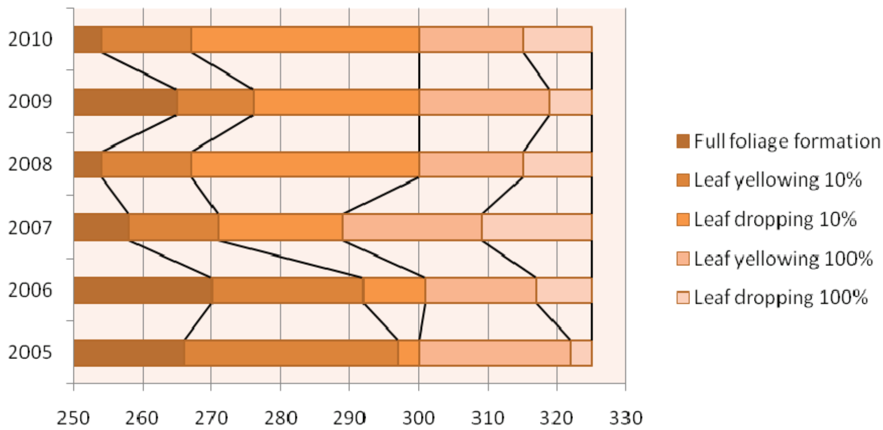
Previous studies were focused on effects of climatic factors on the onset of the budbreak and development of foliage and also demonstrated the dependence of these phenophases



4: *Multiregression dependence between the onset of phenological stages on air and soil temperatures*



3: *Onset and duration of spring phenological stages of Fagus sylvatica L.*



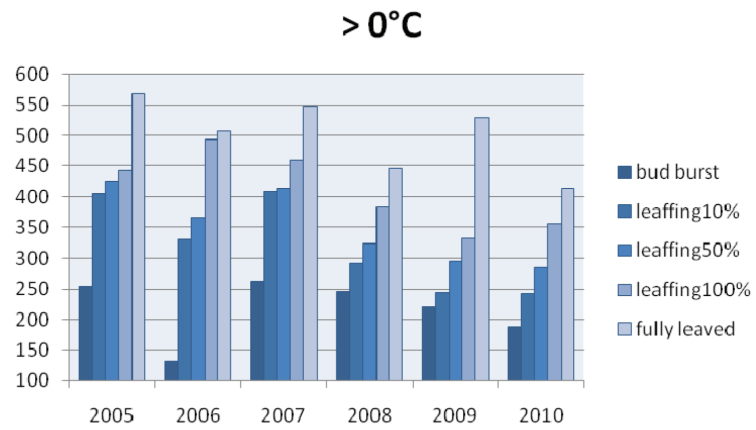
5: *Onset and duration of autumn phenological stages of Fagus sylvatica L.*

on temperatures of both air and soil (Bednářová & Kučera, 2002; Merklová & Bednářová, 2008; Škvareninová, 2008; Bednářová *et al.*, 2011 and 2013). However, factors influencing the budbreak and beginning of development of leaves could not be definitely distinguished and for that reason it was necessary to evaluate them as a complex of factors.

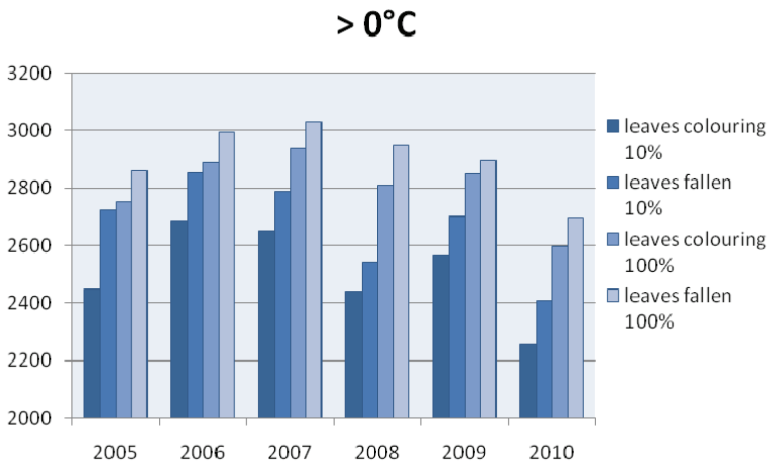
Onsets and durations of autumn phenophases (Fig. 5) were influenced not only by temperatures but also on the sum of precipitations in late summer and early autumn. In individual years of the study period, the beginning and duration of individual phenophases was rather variable. The beginning of the stage of 10% of yellow leaves was recorded in average on the 262nd day of the calendar year (with the variability of 16 days). The first visible cast of 10% of leaves was observed on the 278th day of the calendar year, i.e. 16 days after the beginning of leaf discolouration (yellowing). In individual years, the variability of this phenophase was 30 days. All (i.e. 100%) leaves were yellow on the 298nd day of the calendar year. The onset of the stage of a complete (100%) leaf cast occurred in average on the 316nd day of the calendar year.

According to Larcher (1988), those phenological processes that were taking place in forest woody species in the second half of the year could be influenced by different environmental factors; individual phenological processes could be either accelerated or decelerated by existing ambient conditions. This author attached the maximum importance to the temperature because it could accelerate synthetic activities of plants. Among other important factors influencing the leaf abscission and transition to the period of dormancy, he enumerated reserves of nutrients and water as well as the effect of the diurnal photoperiod. Final phenophases occured in the period when temperatures dropped below the threshold value of + 5 °C (Larcher, 2003). These observations were in harmony also with our results. Many authors (e.g. Škvarenina *et al.*, 2006; Škvareninová, 2013; Priwitzer & Minďáš, 1998) associated the onset of late autumnal phenophases with the preceding rapid decrease of temperatures and beginning of a period of more frequent precipitations. These data were corroborated also in our long-term study on European beech performed in the study area located in the Drahanská vrchovina uplands.

According to many authors, the temperature requirements concerning the onset of individual phenophases of plants can be satisfied at best by means of a cumulative sum of temperatures (Havlíček, 1986; Larcher, 2003; Bagar & Nekovář, 2007; Hájková *et al.*, 2010). The time of the onset of spring phenophases is dependent on the moment when certain temperature limits are exceeded. Sums of diurnal temperatures (TS0) higher than 0 °C were used as a biological criterion for the assessment of their effect on the beginning of spring and autumnal phenophases. These results are presented in Figs. 8 and 9. Within the evaluated period (2005–2010), the onset of the budbreak phenophase in European beech was observed at the moment when the value of TS0 was equal to 216.8 °C. The lowest sum of temperatures in the period before the beginning of this phenophase was recorded in 2006, viz. TS0 = 131.8 °C. On the other hand, however, the highest value of TS0 (263.4 °C) was recorded in 2007. The onset of the ten-per-cent leaf development stage occurred in average when the value of TS0 was 319.9 °C, the beginning of the fifty-per-cent leaf development stage was recorded in the moment when the value of TS0 was 351.3 °C, and the onset of the last stage of leaf development (100%) occurred in the moment when the value of TS0 was 411.0 °C. Finally, the onset of the phenophase of a fully developed leaf area was observed in the moment when the sum of temperatures TS0 was 501.7 °C. The beginning of the stage of 10% of yellow leaves was recorded in the moment when the value of the sum of air temperatures TS0 was 2,509.1 °C and the stage of completely (100%) yellow eaves began at TS0 = 2 806.3 °C. In average, the beginning of the phenophase of leaf abscission (10%) was observed in the moment when the value of TS0 was



6: *Sums of air temperature over 0 deg. C related to spring phenological stages*



7: *Sums of air temperature over 0 deg. C related to autmn phenological stages*

equal to 2,669.9 °C and the stage of a complete (100%) leaf-fall occurred at the sum of air temperatures of 2,904.8 °C.

The duration of spring phenophases (from the stage of budbreak to that of fully developed foliage) was dependent above all on weather conditions existing in individual years. In the course of the whole long-term study period (i.e. 1991–2004) this time interval was in average 32 days. Within the period of 2005–2010 the total length of spring phenophases of European beech (*Fagus sylvatica* L.) was reduced to 27 days. This phenomenon can be explained by the fact that in recent years the temperatures measured in April and at the beginning of May were higher.

In recent years, the total length of the growing season of European beech has been increasing. Within the period of 1991–2005 the duration of the growing season, i.e. from budbreak to the stage of a complete (100%) leaf-fall was 205 days while in years 2005–2010 this period was longer by 5 days (i.e. 210 days). As compared with the long-term average, the period from the stage of budbreak till that of completely (100%) yellow leaves was also protracted (by two days). During autumn monthsmeasured air and soil temperatures were higher and this resulted in a delayed leaf fallen. The period of a reduced assimilation is shortening and this may result in a depletion of reserve assimilates and a deterioration of the health condition of forest stands. Similar conclusions were published aslo by other authors (e.g. Hájková *et al.*, 2010; Škvareninová, 2013; Bednářová, Merklová, 2007; Bednářová *et al.*, 2011). A shortening of the duration of spring phenophases as well as a protraction of the growing season can be explained on the base of ongoing climatic changes.

CONCLUSIONS

The obtained results corroborate that the onset of individual spring phenophases is very variable and depends on the course of weather condition. In the study area, this concerns above all air and soil temperatures. The locality under study is situated in the region with enough rainfalls during the spring phenophases so that they are not negatively influenced by the water deficit.

In average, the stage of budbreak of European beech (*Fagus sylvatica* L.) occurred on the 107th

day of the calendar year. The phenophase of ten percent of leaves was recorded on the 116th day of the calendar year and those of fifty and hundred percent of leaves were observed on the 122nf and the 134th day of the calendar year, respectively. The phenophase of fully developed foliage was recorded in average on the 134th day of the calendar year. The greatest variability of the onset of phenophases was observed in the phenophase of budbreak. The beginning of this phenophase was dependent at most on the end of winter and air and soil temperatures existing already in early spring. The statistical analysis demonstrated a high dependence of the budbreak phenophase on air and soil temperatures existing in the preceding month. In European beech, the onset and duration of autumnal phenophases was influenced not only by temperatures but also by precipitations occurring in the late summer and during the autumn. In the course of autumn, the shortening of the daylight period and a decrease in night temperatures were another important factors. The phenophase of leaf yellowing (10%) occurred on the 262nd day of the calendar year. The stages of 10% and complete (100%) leaf abscission began in average on the 278th and the 298th day of the calendar year, respectively. Final phenophases occurred in the period when temperatures dropped below the threshold value of + 5° C for a period of several days.

Temperature requirements enabling the onset of individual phenophases (as expressed by means of a cumulated sum of temperatures) indicated that within the period 2005–2010 the average sum of temperatures required for the beginning of budbreak was TS0 = 216.8 °C. Within the whole study period (1992–2010), the lowest sum of temperatures enabling the budbreak of European beech was TS0 = 70.8 °C. However, even this very low value was sufficient to induce the phenophase of budbreak. In individual years, the range of temperatures required for the induction of this phenophase was relatively wide. Of all phenophases, this one was the most variable and in average was as much as 36 days.

The duration of individual spring phenophases was dependent on weather conditions existing in individual years. Within the framework of the long-term monitoring of European beech (1991–2004), the duration of the period starting with the budbreak and ending with a fully developed leaf area was 32 days. Within the period of 2005–2010, however, this period was shorter (27 days). In recent years, the growing season of European beech in the study area was longer and longer. As compared with results of a long-term study, it extended from 205 days to 210 days. This means that an extension of the growing season and, thus, a shortening of the period of dormancy might have a negative effect on the health condition of forest stands.

SUMMARY

This paper presents results of a study on phenophases of European beech (*Fagus sylvatica* L.) performed within the period of 2005–2010. This study was linked up with a long-term study that was started in 1992. Although the onset of individual phenophases is predetermined by genetic properties of each plant species, the weather may influence the onset of individual phenophases and thus disturb the growth and development of plants. In individual years, dates of the onset and the duration of individual phenophases differed considerably and were dependent on the course of weather. In European beech, temperature requirements enabling the onset of individual phenophases were expressed as sums of temperatures recorded in periods preceding each of the phenophases under study. The authors elaborated cumulative sums of air temperatures higher than 0 °C for each period that preceded individual phenophases under study. In individual years, these sums were rather different. Of all phenophases, the stage of budbreak was the most variable. It was found out that for the onset of spring phenophases both air and soil temperatures were of crucial importance. The statistical analysis of obtained results demonstrated that these two variables should be evaluated in conjunction. As compared with the long-term average data the period between the budbrak and full development of leaf area was shorter and shorter due to the occurrence of higher temperatures in spring months in recent years. On the other hand, the duration of autumnal phenophases gradually extended. It is well-known that the dormancy is quite indispensable for a good health condition of forest woody species. However, because of this phenomenon, the total duration of the growing season was extended while that of the dormancy period was shortened so that it can be concluded that this phenomenon could endanger the health condition of forest stands.

Acknowledgement

The present study was supported by the OP Education for Competitiveness (European Social Fund and the state budget of the Czech Republic). Project Indicators of trees vitality Reg. No. CZ. 1.07/2.3.00/20.0265.

REFERENCES

AMANO, T., SMITHERS, R., SPARKS, T., SUTHERLAND, E. 2010. A 250 – year index of first flowering dates and its response to temperature changes. In: *Proceedings*. *Phenology 2010 – climate change and adaptations.* Dublin, Ireland, June 14–18, 2010, 42.

BAGAR, R., NEKOVÁŘ, J. 2007. Porovnání růstových podmínek v I–IV. vegetačním stupni. In: *Proceedings of International Scientific Conference – Bioclimatology and natural hazards.* September 17–20, 2007. *Procedings.* Polana nad Detvou: Slovenská bioklimatologická spoločnost a TU vo Zvolene, 1–7.

BARTOŠOVÁ, L., BAUER, Z., TRNKA, M., ŠTĚPÁNEK, P., ŽALUD, Z., 2010: Klimatické faktory ovlivňující nástup a délku trvání fenofází vybraných rostlinných druhů na lokalitách jižní Moravy v letech 1961–2007. *Acta univ. agric et. silvic. Mendel. Brun.*, 58(2): 35–44.

BEAUBIEN, E., HAMANN, A. 2010. Spring flowering response to climate change over 70 years in central Alberta, Canada. *Procedings*. *Phenology 2010 – climate change and anaptations.* Dublin, Treland, June 14–18, 2010, 47.

BEDNÁŘOVÁ, E., KUČERA, J. 2002. Phenological observations of two spruce stands (*Picea abies* /L./ Karst.) of different age in the years 1991–2000. *Ekológia (Bratislava)*, 21(1): 98–106.

BEDNÁŘOVÁ, E., MERKLOVÁ, L. 2007. Results of monitoring the vegetative phenological phases of European beech (*Fagus sylvatica* L.) in 1991–2006. *Folia oecologica*, 34(2): 77–85.

BEDNÁŘOVÁ, E., MERKLOVÁ, L. 2007. Fenologické a růstové fáze u buku lesního (*Fagus sylvatica* L.). In: *International Scientific Conference – Bioclimatology and natural hazards.* September 17–20, 2007. Polana nad Detvou: Slovenská bioklimatologická spoločnost a TU vo Zvolene, 28–31.

BEDNÁŘOVÁ, E., KUČERA, J., MERKLOVÁ, L. 2010. The onset and duration of vegetative phenological staged in European beech (*Fagus sylvatica* L.) under changing conditions of the emvironment. *Acta univ. agric. et silvic. Mendel. Brun.*, 58(4): 23–30.

BEDNÁŘOVÁ, E., MERKLOVÁ, L., 2011: Evaluation of vegetative phenological stages in a spruce monoculture depending on parameters of the environment. *Acta univ. agric. et silvic. Mendel. Brun.*, 59(6): 31–36.

BEDNÁŘOVÁ, E., SLOVÍKOVÁ, K., TRUPAROVÁ, S., MERKLOVÁ, L. 2013. Results of a phenological study of the European larch (*Larix decidua* Mill.) growing in a mixed stand. *Acta univ. agric. et silvic. Mendel. Brun.*, 61(5): 1239–1246.

GÖMÖRY, D. 2010. Klimatická zmena a krajina. In: ŠKVARENINA, J., SZOLGAY, J., ŠIŠKA, B., LAPIN,M., (ed.) *Študia Slovenskej bioklimatologickej spoločnosti SAV,* XXV, roč. XXII, Zvolen: TU Zvolen.

HÁJKOVÁ, L., NEKOVÁŘ, J., RICHTEROVÁ, D. 2010. Assessment of vegetativephenological phases of European beech (*Fagus sylvatica* L.) in relation to effective temperature during period of 1992–2008 in Czechia. *Folia oecologica.*, 37(6): 152–161.

HÁJKOVÁ, L., VOŽENÍLEK, V., TOLASZ, R. 2012. *Atlas fenologických poměrů Česka,* UP Olomouc: ČHMÚ Praha.

HAVLÍČEK, V. 1986. *Agrometeorologie,* Praha: SZN Praha.

LARCHER, W. 1988. *Fyziologická ekologie rostlin*. Praha, Academia Praha.

LARCHER, W. 2003. *Physiological Plant Ecology.* Berlin, Heidelberg, Springe-Verlag.

MERKLOVÁ, L., BEDNÁŘOVÁ. 2008. Results of a phenological study of the tree layer of mixed stand in the region of the Drahanská vrchovina Upland. *J. For. Sci.*, 54(7): 294–305.

MOŽNÝ, M., NEKOVÁŘ, J. 2007. Dlouhodobé kolísání počátku vegetační sezony v Polabí v letech 1876–2005. *Meteorologické zprávy,* 60(4): 23–26.

PRIWITZER, T., MINĎÁŠ, J. 1998. Výsledky fenologických pozorování lesnych drevin v rokoch 1993–1997 na lokalite Polana – Hukavský Grůň. *Vedecké práce LVÚ vo Zvolene.* 42: 17–32.

SPARKS, T. H., HUBER, K., CROXTON, P. 2006. Plant development scores from fixed – date photographs: the influence of weather variables and recorder experience. International Journal of Biometeorology, 50(5): 275–279.

ŠKVARENINOVÁ, J. 2008. Start of spring phenophases in oak (*Quercus robur* L.) in Zvolenská Basin in relation to temperature sums. *Meteorological Journal,* 11(1–2): 15–20.

ŠKVARENINOVÁ, J. 2009. *Fenológia rastlin v meniacich sa podmienkach prostredia*. Zvolen: TU Zvolen.

ŠKVARENINOVÁ, J. 2010. Priebeh jarných fenologických fáz na generativnych orgánoch autochtnnych populácií smreka obyčajného (*Picea abies* /L./ Karst zo Slovenska. *Lesnický časopis – Forestry journal*, 56(4): 369–381.

ŠKVARENINOVÁ, J. 2013. *Vplyv zmeny zmeny klimatických podmienok na fenologickú odozvu ekosystemov.* Zvolen: TU vo Zvolen.

ŠKVARENINA, J., ŠKVARENINOVÁ, J., SNOPKOVÁ, Z., KOVÁČIK, M., STŘELCOVÁ, K. 2006. Fenologické prejavy listnatych lesnych drevin v horskom pralesovom ekosystéme Jedlobučiny v Kremnických vrchoch. In: *International Scientific Conference – Fenologická odezva proměnlivosti podnebí.* 22. 3. 2006. *Proceedings of.* Brno ČHMÚ, 2–8.

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